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The Performance of Roofing Made With Asplund Felts

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THE PERFORMANCE OF ROOFING MADE WITH ASPLUND FELTS

Sidney H. Greenfeld

A study of the durability of roofing made with Asplund wood fibers was conducted from 1942 to 1967. Concentrations of 0 to 60 percent wood fibers (oak or pine) prepared by three variations of the Asplund process were evaluated. All the mineral-surfaced roll roofings and shingles were performing well after 25 years, with only four specimens showing more deterioration than the controls (only rags and paper in their felts). No differences in performance could be related to the felt composition.

Key Words: Asphalt, Asplund, felt, mineral-surfaced roll roofing, shingles, wood fibers.

1. Introduction

Organic felts, because of their importance in asphalt roofing systems, have been the object of continual study by the Asphalt Roofing Manufacturers Association[1] since the Association established a Research Fellowship at the National Bureau of Standards in 1926. At that time felts were made primarily of rags. Additions of various materials, such as newspapers and sawdust, were being made to the felt to obtain flexibility, absorptivity and other properties not found in the largely rag felts. Wood fibers were being substituted for part of the rags. These additions and substitutions were made as matters of necessity before their effects were fully understood. However, the industry was interested in knowing how these materials were affecting the durability of the systems in which the felts were used. Therefore, they instituted a felt study under Dr. O. G. Strieter, their Research Associate at the NBS, in 1926, which culminated in two publications: one in 1929, on the production of experimental felts [1][2] and the other in 1936, on the weathering of saturated felts and smooth-surface roll roofing made from the experimental felts [2]. The conclusion drawn from this early work was that "there was no significant difference in the resistance to weathering of asphalt roofing which may be attributed to the kind of fiber or combination of fibers employed" [2]. In 1941, the asphalt

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1 Formerly Asphalt Roofing Industry Bureau

2 Figures in brackets indicate references at the end of this paper.

roofing industry was rapidly increasing its production to meet the demands of the war-time construction boom. The European and Asian sources of rags were becoming less available, and the Asplund process for defibrating wood had recently been introduced [3] and hesitatingly accepted by the roofing industry. The industry had performed laboratory tests and limited exposures of products made with these wood fibers, but they wanted a controlled, unbiased evaluation of the long-term effects wood fibers might have on the durability of its products. Consequently, in 1942, a comprehensive exposure program was started under the Research Associate plan at the National Bureau of Standards by the Asphalt Roofing Manufacturers Association.

This program was designed to evaluate hard- and soft-wood fibers in concentrations up to 60 percent of the dry felt weight. The effects of heat and chemical treatment of the fibers were also studied. Furnishes containing these wood fibers were commercially processed into saturated felts, smooth-surface roll roofing, mineral-surfaced roll roofing and hexagonal shingles, which were exposed to the weather in Minneapolis, Minnesota; Mobile, Alabama and Washington, D. C. The results of the saturated-felt and smooth-surface roll roofing exposures were reported in 1948 [4]. However, all of the mineral-surfaced specimens looked essentially the same at that time, nor had enough time lapsed for differences to be expected. This report covers 25 years' exposure of these specimens in Washington, D. C. only; inspections in Minneapolis and Mobile were discontinued during the 1950's. The last Mobile inspection was made in 1950 and the last Minneapolis inspection in 1958. At these inspections all of the shingles were rated "excellent",[3] but differences were noted in the roll roofings. The conclusions drawn at the last Mobile inspection were that felts made with Asplund fibers produced products that weathered as well as those made with rag and paper felts and that, if the coarse fiber bundles were removed, "there is no limit to the quantities of (Asplund wood) fibrous materials that can be incorporated into the felts" (within the range covered by this study). In 1958, the conclusions drawn in Minneapolis were that the shingles were all in excellent condition and that some blisters and surface cracks were appearing in many of the mineral-surfaced roll roofings. However, the two specimens with heat treated oak (E-1 and E-2 in Table 1) were still rated "excellent" and those with 30 percent chemically treated pine and oak were rated "good". All of the specimens had retained the same ratings from 1950 to 1958, leading to the conclusion that the few blisters and cracks present had appeared early during exposure and had not gotten appreciably worse during the following eight years' exposure.

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[3] The specimens were inspected visually by local laboratory people and rated "excellent", "good", "fair" or "poor" according to their appearance.

In attempting to interpret the results of this study, it must be kept in mind that the study was started in 1942 without the benefit of a statistically sound design. The inspections were conducted over the years by different inspectors and the ratings were made subjectively. Therefore, little weight can be given to small differences in ratings among the specimens; only major deviations from the performance of the control should be considered.

2. Materials

The primary variable in this study was the felt composition (furnish). Every other component of the finished roof was kept as uniform as possible.

2.1. Felts

The felt furnishes, other than the Asplund fibers, consisted of rags and paper. The Asplund fibers were prepared by one of three processes, described in detail by Ritter [5]. Briefly, the wood was reduced to chips by passing logs through rapidly rotating blades, passed over a magnetic separater to remove ferrous contaminants, preheated with steam at 140 to 170 psi[4] for one and a quarter minutes and forced between two grinding discs, one fixed and one rotating at high speed, to produce wood fibers. The output was sent through screens to remove the incompletely separated fiber bundles. The fine wood fibers are called Asplund fibers, after the developer of this process.

The heat-treated and chemically treated fibers were made by using the Asplund defibrator in combination with a B-K reaction chamber. In this combination, additional periods of heating can be employed to produce the heat-treated fibers or caustic soda (NaOH) can be added to make the chemically treated fibers. The time-temperature-concentration relationships vary with the types of wood used and are designed to produce the types of fibers desired. The heat-treated fibers received seven minutes of steam treatment prior to grinding and the chemically treated fibers were soaked in a hot three percent caustic solution followed by five minutes of steam prior to defibration.

The wood fibers in suspension were blended with paper, from a Hydropulper, and rags, from beaters, also in suspension,to produce the 13 different furnishes used. The characteristics of the felts produced appear in Table 1. The fiber classification of the felts appears in Table 2.

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[4] 1 lbf = 4.45 newtons (approximately)
1 in. = 2.54 cm (exactly)

The felts described in Table 1 were all produced in 36-inch rolls on the same commercial felt-making machine. Felt A-1 contained no Asplund fibers and was used as the control. All of the felts containing Asplund fibers were both less pliable and weaker than the control, and they all had higher asphalt capacities. The Asplund felts were all thicker than the control, partially accounting for their being stiffer, but the stiffness of the Asplund felts was not quantitatively a function of their thickness. Similarly, there was no quantitative relation between tensile strength (per inch of width) and thickness or composition.

2.2 Asphalts

The felts for the roll roofing and shingles were commercially saturated with different saturants. The characteristics of these saturants are reported in Table 3. The softening points of these saturants are somewhat higher than those in current use.

The physical characteristics of the saturated felts with which the roll roofing and shingles were made are tabulated in Table 4. All of these products meet or exceed the minimum saturation and strength requirements of current ASTM and Federal specifications for roll roofing and shingles.[5]

Both the mineral-surfaced roll roofing and shingles were prepared by coating the felts with a stabilized asphalt and surfacing them with green ceramic granules. The properties of the coating asphalt and the stabilizer content are reported in Table 5.

Because all of the specimens were made from the same coating on the same commercial machine, no further information was obtained on the coating. The weights of the roll roofing specimens, their total bitumen contents (saturant and coating), their total ash contents and their pliabilities are reported in Table 6. The weights, bitumen contents and ash contents of the shingles are reported in Table 7. The figures in these two tables are presented more to show the uniformity of the specimens than to establish differences among them. The mineral-surfaced roll roofing specimens were all heavier than the minimum weight required by ASTM (D 249), but the shingles were lighter than required by ASTM D 226-65. However, when these specimens were exposed, type 210 shingles were being manufactured instead of type 235, and these specimens met the requirements for type 210 shingles.

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[5] ASTM D 249-60 and Fed. Spec. SS-R-630 Asphalt Roll Roofing Surfaced with Mineral Granules; ASTM D 225-65 and Fed. Spec. SS-S-300 Asphalt Shingles Surfaced with Mineral Granules.

Table 1. Composition and Physical Characteristics of Dry Felts

No.	Rags %	Paper %	Asplund Type	Asplund Fiber %	Weight lbs/420 ft^2 [c]	Caliper Mils	Pliability passing[a]	Tensile Strength with fiber grain lb/per inch width	Asphalt Capacity[b] %
A-1	73	27	None	None	49.0	55	3/32 in.	32	180
B-1	55	30	Untreated pine	15	50.2	59	1/4 in.	31	187
B-2	37	33	Untreated pine	30	52.9	63	1/2 in.	28	187
C-1	57	28	Untreated oak	15	51.9	60	1/2 in.	26	192
C-2	37	33	Untreated oak	30	46.6	61	3/4 in.	25	215
D-1	45	30	Heat-Treated pine	25	52.8	62	1/2 in.	30	175
D-2	0	50	Heat-Treated pine	50	49.0	75	1 in.	24	225
E-1	40	30	Heat-Treated oak	30	50.2	64	1 in.	29	206
E-2	20	30	Heat-Treated oak	50	53.7	69	1-1/2 in.	28	220
F-1	38	32	Chem. Pine	30	52.4	65	1/2 in.	30	186
F-2	30	30	Chem. Pine	40	50.6	64	3/4 in.	30	218
G-1	42	28	Chem. Oak	30	50.2	60	3/4 in.	31	214
G-2	0	40	Chem. Oak	60	49.7	67	1-1/4 in.	25	214

[a] Minimum diameter of mandrel which will not cause failure.

[b] Burette Method - Asphalt Capacity = (Kerosene Number)x(Sp.Gr. Asphalt)

[c] 1 lb = 0.45 kg

Table 2. Fiber Classification of Felts

No.	A-1	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2	G-1	G-2
Retained on 10-mesh sieve, %	7.3	9.4	9.8	9.8	13.1	13.8	12.7	10.5	12.0	10.8	12.5	11.4	19.4
Passing 10-mesh, retained on 28-mesh sieve, %	29.7	30.3	28.4	23.1	25.6	27.4	33.2	28.7	29.0	29.6	29.8	25.3	25.7
Passing 28-mesh, retained on 48-mesh sieve, %	19.4	18.0	16.7	17.1	17.4	15.6	16.7	17.4	18.9	17.2	16.8	17.8	17.4
Passing 48-mesh, retained on 200-mesh sieve,%	26.8	25.1	22.2	24.9	23.7	21.7	18.5	23.2	21.0	22.3	21.0	24.8	18.9
Passing 200-mesh sieve, %	16.8	17.2	22.9	25.1	20.2	21.5	18.9	20.2	19.1	20.1	19.9	20.7	18.6

Table 3. Asphalt Saturants Used in the Roll Roofing, and Shingles

Asphalt	Softening Point[a] R & B °F (°C)	Penetration[b] 25°C, 100g 5 sec.	0°C, 200g 60 sec.	46°C, 50g 5 sec.
Roll Roofing	130 (54)	74	28	> 200
Shingles	169 (76)	31	15	78

[a] D 36-66T Softening point of asphalts and tar pitches (Ring-and-Ball Apparatus)

[b] D 5-65 Penetration of Bituminous Materials

Table 4. Physical Characteristics of Saturated Felts

No.	Weight Lb/100 ft^2	Caliper Mils	Saturant Lb/100 ft^2	Saturation[a] %	Saturation[a] Efficiency	Pliability 90° 3/4 in. (19.1mm) Mandrel Machine Direction With	Pliability 90° 3/4 in. (19.1mm) Mandrel Machine Direction Across	Tensile Strength with fiber grain lb/in	Extracted Felt Lb/100 ft^2
A-1	29.2	63	18.3	170	95	passed	passed	76	10.8
B-1	31.2	62	20.4	187	100	"	"	80	10.8
B-2	30.8	65	20.7	205	110	"	"	70	10.1
C-1	28.8	60	20.4	199	104	"	"	65	10.3
C-2	31.5	62	20.9	199	93	"	"	70	10.6
D-1	31.3	73	20.3	184	94	"	"	72	11.0
D-2	37.2	78	27.2	273	121	"	"	72	10.0
E-1	33.1	65	21.9	198	96	"	"	79	11.1
E-2	29.8	62	20.5	220	100	"	"	70	9.3
F-1	33.7	72	22.3	196	105	"	"	72	11.4
F-2	34.8	71	22.9	192	88	"	"	78	11.9
G-1	29.1	63	18.2	169	83	"	"	75	10.8
G-2	31.9	70	21.9	221	103	"	"	58	9.9

[a] Efficiency = $\left(\frac{\text{Percent Saturation}}{\text{Asphalt Capacity}}\right) \times 100$

Table 5. Coating Asphalt

Softening Point, R & B, °F (°C)	219 (104)
Penetration at 77°F (25°C), 1/10 mm	16
Stabilizer Content, %	35

Table 6. Characteristics of Mineral-Surfaced Roll Roofing

No.	Weight $lb/100\ ft^2$	Total Ash $lb/100\ ft^2$	Total Bitumen $lb/100\ ft^2$	Pliability at 77°F (25°C) 90°-3/4-in. mandrel Machine Direction With	Across
A-1	83.7	34.1	38.8	1 of 6 failed	passed
B-1	82.5	30.8	41.6	passed	"
B-2	84.4	33.4	40.6	"	"
C-1	82.6	34.1	38.3	"	"
C-2	83.0	32.6	41.4	"	"
D-1	82.4	32.5	38.7	"	"
D-2	83.4	31.7	41.8	1 of 6 failed	"
E-1	82.7	31.7	40.1	passed	"
E-2	83.0	30.6	40.8	1 of 6 failed	"
F-1	83.8	31.8	41.1	1 of 6 failed	"
F-2	83.4	32.1	41.0	passed	"
G-1	83.4	33.1	39.7	1 of 6 failed	"
G-2	81.0	32.8	38.8	passed	"

Table 7. Asphalt Shingles

No.	Weight lb/100 ft^2	Total Ash lb/100 ft^2	Total Bitumen lb/100 ft^2
A-1	80.7	33.2	37.9
B-1	86.3	38.2	37.9
B-2	82.8	34.8	38.0
C-1	79.7	33.0	37.5
C-2	84.2	34.4	39.8
D-1	81.6	32.6	38.1
E-1	80.0	31.6	38.1
F-1	86.8	35.2	40.8
F-2	86.7	33.2	42.8
G-1	83.4	32.5	40.3
G-2	85.8	35.8	40.0

3. Procedures

3.1. Specimen Preparation

The felts were made in a commercial felt mill, saturated in a commercial saturator and made into finished products on a commercial roofing machine. Conditions of operation, saturants, coatings and granules were kept as nearly uniform as possible in order to maintain the felt furnish as the principle variable.

3.2. Exposure

The specimens were exposed on specially constructed roof decks, made from 1 x 6-inch straight sided sheathing boards. The decks were installed on the roof of the Industrial Building at the old National Bureau of Standards site facing due south at an inclination of 45°. The specimens were applied directly to the decks, each specimen covering a 3 x 9-foot area. Each of the mineral-surfaced roll roofing specimens was cut to contain two two-inch head laps, fastened with roofing nails two-inches on centers.

The hexagonal shingles were also applied directly to the decks without an underlayment in the manner prescribed for hexagonal shingles.

3.3. Inspections

Periodically the exposure specimens were inspected visually by the members of the Research Committee of the Asphalt Roofing Manufacturers Association and representatives of the National Bureau of Standards. No attempt was made to give absolute ratings to the specimens; only relative performances were evaluated.

The letter designations for the inspectors were made to differentiate among them, only, and any particular designation, such as "A", does not refer to the same person at different inspection periods. Where the specimens have been rated numerically, the following ratings prevail:

3 = Excellent
2 = Good
1 = Poor

Other inspectors on other occasions rated the specimens verbally without attempting to quantify the ratings.

4. Results

The members of the Research Committee and representatives of the National Bureau of Standards inspected the Washington, D. C. exposures in 1948, 1954, 1958 and 1965. Photographs were taken in October 1958 and April 1967.

The results of the 1948 inspection, after six and a half years of exposure, were reported qualitatively. The shingles were performing better than the mineral-surfaced roll roofing. A small amount of blistering was becoming apparent on the roll roofing but weathering had not progressed far enough to permit evaluation of deterioration resulting from differences in the composition of the felt [4].

In May of 1954 the exposures, then over twelve years old, were inspected again. The shingles were still in excellent condition but some deterioration had become apparent in the mineral-surfaced roll roofing. One of the eight inspectors had reported that B-2 and E-2 were not performing satisfactorily and B-1 and G-2 were "less than good". The other seven inspectors rated all of the specimens "good". Thus, twelve years was the earliest period in which differences in deterioration appeared and these differences were considered significant by only one observer. There was no consistent pattern of deterioration relating to felt composition in these twelve year observations. The nature of the defects was not reported.

The next comprehensive inspection was made in 1958. Like the other inspections, this one was made by the members of the Research Committee and a representative of the National Bureau of Standards. The ratings were based on the appearances of the specimens relative to how each inspector thought they should be after 16 years of exposure. Because of the subjective nature of this type of inspection, the performances of the specimens relative to the control (A-1) becomes the primary consideration. Sufficient differences in deterioration among the specimens existed in 1958 to warrant duplication of the inspection summaries in Table 8.

It is interesting that the inspector who had rated roll roofings E-2 "fair" and B-1 and G-2 "less than satisfactory" in 1954 rated them excellent in 1958. This change in rating illustrates that it is extremely difficult to project long-term performance from early observations.

After 16 years of exposure, only one composition of felt (B-2) had produced a mineral-surfaced roll roofing product that had performed less satisfactorily than the control. B-2 had been among the poorer performers in 1954, also. It contained the higher concentration (30%) of unmodified pine Asplund fibers. On the other hand, the chemically treated pine and the unmodified oak fibers produced products that were outperforming the control.

The shingles were all still performing extremely well and all but four were rated excellent by all of the inspectors. One inspector rated C-2, E-1, F-2 and G-1 good. E-1 (30% heat treated oak) and G-1 (30% chemically treated oak) were also among those performing less than excellently among the roll roofing.

A 23-year inspection of these materials was made in 1965 by five members of the Research Committee. This was the only inspection in which blistering and cracking were observed as well as general appearance. The results are presented in Table 9.

All of the mineral-surfaced roll roofing showed some signs of deterioration, but all were still performing satisfactorily; none was considered a failure. Nine of the twelve Asplund felts were outperforming the control. Only three were less satisfactory: B-1 and B-2, containing 15% and 30% untreated pine, and E-2, containing 50% heat-treated oak. These three also contained appreciable quantities of rags. Both B-1 and B-2, because of their high rag contents, had low asphalt capacities, but E-2 had a high capacity. The efficiency of saturation of all three exceeded the 90 percent level. Specimens with low saturation efficiencies (F-2, G-1) were outperforming the control. Thus, performance does not seem to be related to felt furnish or efficiency of saturation in the ranges of these variables covered in this study.

In general, all of the shingle specimens were performing excellently after 23 years of exposure. Only one shingle specimen (C-2) was performing appreciably worse than the control. This one contained 37 percent rags, 33 percent paper and 30 percent untreated oak. The same felt produced mineral-surfaced roll roofing that was outperforming the control. Therefore, again it is not possible to blame its poor performance on the felt furnish.

No group inspection was made after 25 years of exposure, but photographs were taken of all of the specimens. Examination of the photographs revealed that little change had occurred in any of the specimens since the 1965 inspection (23 years' exposure). Even the specimens rated "poor" in 1965 were still performing adequately. Photographs of the three roll roofing specimens and one shingle specimen that showed the worst deterioration are reproduced in Figures 1 to 4. Figure 5 is of the control.

5. Conclusions

One important conclusion can be drawn from this comprehensive exposure program. All of the specimens have given a more-than-satisfactory performance during their 25 years of exposure. Small differences in deterioration were observed after 16 years of exposure, but none was related to felt furnish. Durable shingles and mineral-surfaced roofing can be made from organic felts irrespective of the type or quantity of Asplund fibers in the ranges covered in this study.

Table 8

Asplund Felt Specimens After 16 Years of Exposure in Washington, D. C.

1958

Mineral-Surfaced Roll Roofing

Specimen No.	Inspector A	B	C	D	E	F	G	H	Average
A-1	3	3	3	2	3	3	3	3	2.9
B-1	3	3	3	2	3	3	3	3	2.9
B-2	2	3	2	2	3	3	2	3	2.5
C-1	3	3	3	3	3	3	3	3	3.0
C-2	3	3	3	3	3	3	3	3	3.0
D-1	3	3	3	2	3	3	3	3	2.9
D-2	3	3	3	2	3	3	3	3	2.9
E-1	3	3	3	2	3	3	3	3	2.9
E-2	3	3	3	2	3	3	3	3	2.9
F-1	3	3	3	3	3	3	3	3	3.0
F-2	3	3	3	3	3	3	3	3	3.0
G-1	3	3	3	2	3	3	3	3	2.9
G-2	3	3	3	2	3	3	3	3	2.9

Table 8 continued on next page

Table 8 - continued

Shingles

Specimen No.	Inspector A	B	C	D	E	F	G	H	Average
A-1	3	3	3	3	3	3	3	3	3.0
B-1	3	3	3	3	3	3	3	3	3.0
B-2	3	3	3	3	3	3	3	3	3.0
C-1	3	3	3	3	3	3	3	3	3.0
C-2	3	3	3	2	3	3	3	3	2.9
D-1	3	3	3	3	3	3	3	3	3.0
E-1	3	3	3	2	3	3	3	3	2.9
F-1	3	3	3	3	3	3	3	3	3.0
F-2	3	3	3	2	3	3	3	3	2.9
G-1	3	3	3	2	3	3	3	3	2.9
G-2	3	3	3	3	3	3	3	3	3.0

3 = Excellent

2 = Good

1 = Poor

Table 9. Asplund Felt Specimens After 23 years of Exposure in Washington, D.C.

1965

Mineral Surfaced Roll Roofing

Insp.	General Appearance						Blisters						Cracks						Grand
No.	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	Average
A-1	2	1	2	2	2	1.8	2	2	2	3	2	2.2	2	2	2	1	1[a]	1.6	1.9
B-1	1	1	1	2	1	1.2	2	2	2	1	2	1.8	1	1	1	1	1	1.0	.1.3
B-2	1	1	1	2	1	1.2	1	1	1	2	1[a]	1.2	1	1	1	1	1	1.0	1.1
C-1	2	2	3	2	2	2.2	3	3	3	3	2	2.8	2	2	3	1	1	1.8	2.3
C-2	2	1	3	2	2	2.0	3	3	3	3	3	3.0	2	3	3	1	2	2.2	2.4
D-1	2	2	3	2	3	2.4	2	3	2	3	3	2.6	2	3	3	1	2	2.2	2.4
D-2	2	1	2	2	2	1.8	3	3	3	3	3	3.0	2	2	2	1	1	1.6	2.1
E-1	1	1	2	2	1	1.6	3	3	3	3	2	2.8	1	2	2	1	1	1.4	1.9
E-2	1	1	1	2	1	1.2	1	1	1	3	1[a]	1.4	2	2	2	1	1	1.6	1.4
F-1	2	2	1	2	2	1.8	3	3	3	3	3	3.0	2	2	2	2	2	2.0	2.3
F-2	2	2	1	2	2	1.8	3	3	3	3	2	2.8	2	2	3	1	3	2.2	2.3
G-1	1	1	2	2	2	1.6	3	3	3	3	3	3.0	1	2	1	1	2	1.4	2.0
G-2	2	1	2	2	2	1.8	2	3	3	3	2	2.6	2	2	2	1	2	1.8	2.1

Table 9 continued on next page

Table 9 - continued

Shingles

Insp.	General Appearance						Blisters						Cracks						Grand
No.	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	Average
A-1	3	3	3	2	2	2.6	3	3	3	3	2	2.8	3	2	3	3	2	2.6	2.7
B-1	3	3	3	2	2	2.6	3	3	3	3	2	2.8	3	3	3	3	2	2.8	2.7
B-2	3	3	3	2	2	2.6	3	3	3	3	3	3.0	3	3	3	2	2	2.6	2.7
C-1	3	3	3	2	2	2.6	3	3	3	3	1	2.6	3	3	3	2	2	2.6	2.6
C-2	2	3	2	2	1	2.0	3	3	3	3	2	2.8	2	3	1	1	1	1.6	2.1
D-1	3	2	3	2	2	2.4	3	3	3	3	2	2.8	3	3	3	3	2	2.8	2.7
E-1	2	3	3	2	2	2.4	3	3	3	3	2	2.8	3	3	3	2	2	2.6	2.6
F-1	3	3	3	2	2	2.6	3	3	3	3	2	2.8	3	3	3	3	2	2.8	2.7
F-2	3	3	3	2	2	2.6	3	3	3	3	2	2.8	3	3	3	3	2	2.8	2.7
G-1	2	2	3	2	2	2.2	2	3	3	3	2	2.6	2	3	3	3	2	2.6	2.5
G-2	3	3	3	2	2	2.6	3	3	3	3	2	2.8	3	2	3	3	2	2.6	2.7

3 = Excellent

2 = Good

1 = Poor

[a] Failure

6. Literature Cited

[1] Shaw, M. B., G. W. Bicking and O. G. Strieter, Experimental Production of Roofing Felts, RP No. 67, J. Res. NBS 2, 1001-1016, 1929.

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[3] Abrahams, H. A., Asphalts and Allied Substances, Fifth Ed., D. Van Nostrand, 1, 728, 1945.

[4] NBS Report, unnumbered, Investigation of Roofing Felts Containing Asplund Fibers, Sept. 1, 1948 (Restricted).

[5] Ritter, G. A., Paper Mill News 67, No. 47, Nov. 18, 1944.

This work was sponsored by the Asphalt Roofing Manufacturers Association at the National Bureau of Standards. The preparation and exposure were supervised by Dr. O. G. Strieter. Inspections were conducted by members of the Research Committee of the Asphalt Roofing Manufacturers Association and Dr. H. R. Snoke, of the National Bureau of Standards.

7. Glossary

<u>Asplund fibers</u> - Wood fibers prepared by a process developed by A. Asplund.

<u>Caliper</u> - The thickness of a material as measured with calipers.

<u>Furnish</u> - The composition of felt in terms of fibers, i.e., rag, wood, paper.

<u>Shingles types</u> - The designation used to describe shingles in terms of the shapes of their tabs and the approximate weight of one square of material.

<u>Shives</u> - Bundles of wood fibers that have not been dispersed.

<u>Square</u> - Quantity of roofing material covering 100 square feet of roof area.

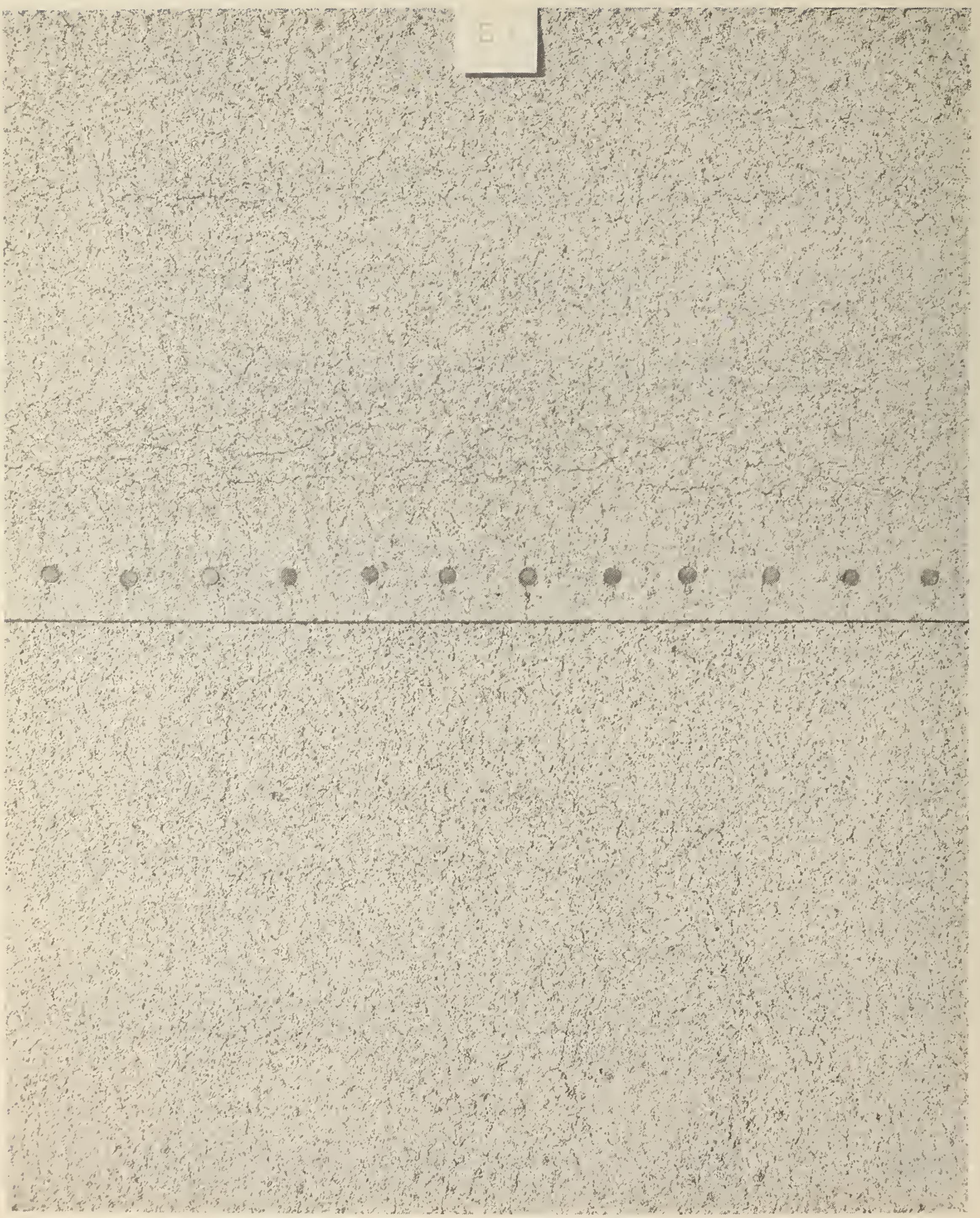

FIGURE 1 - Mineral-Surfaced Roll Roofing B-1 with Felt Composed of 55% Rags, 30% Paper and 15% Pine Fibers. Rated 1.3 out of 3.0 after 23 Years of Exposure.

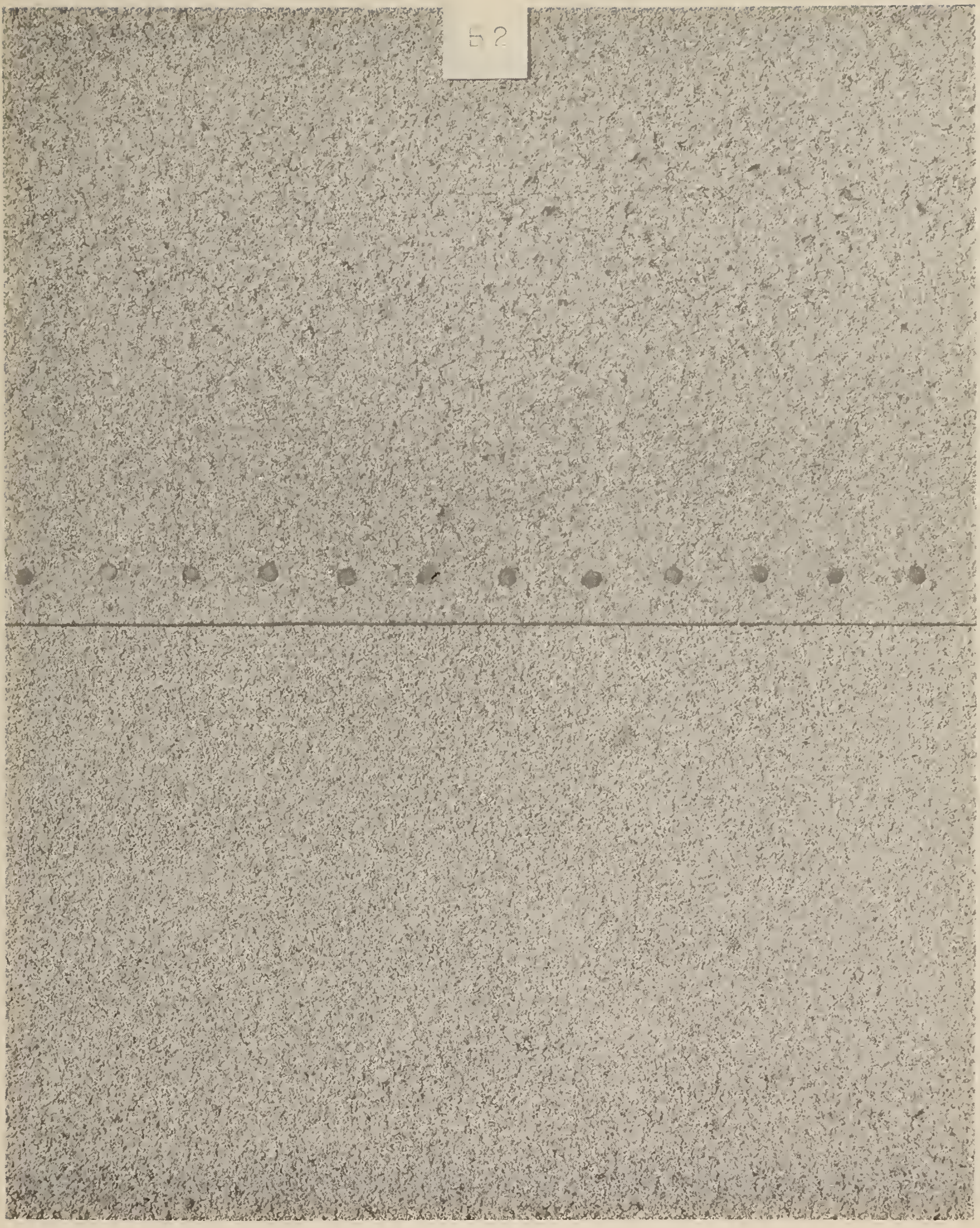

FIGURE 2 - Mineral-Surfaced Roll Roofing B-2 with Felt Composed of 37% Rags, 33% Paper and 30% Pine Fibers. Rated 1.1 out of 3.0 after 23 Years of Exposure.

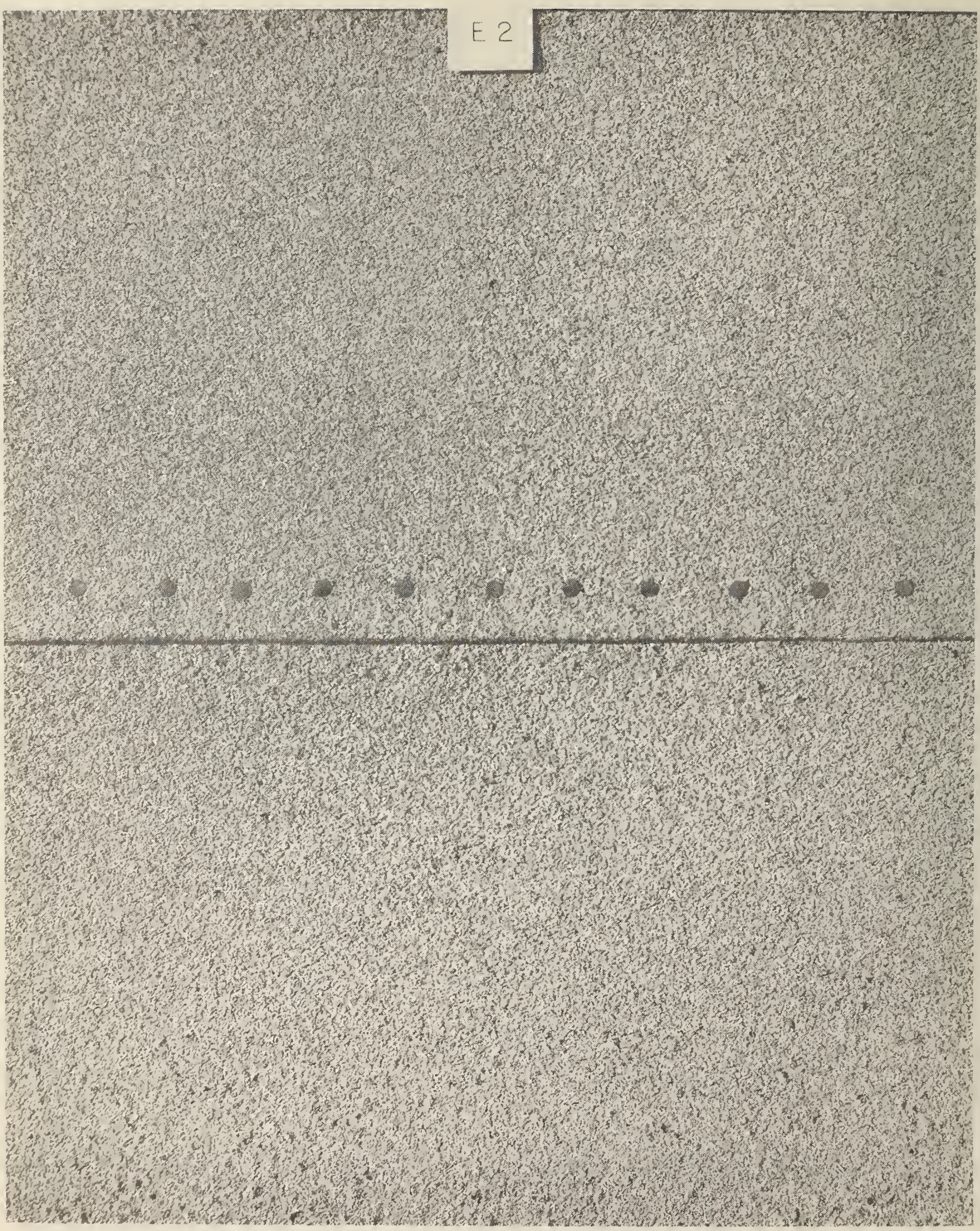

FIGURE 3 - Mineral-Surfaced Roll Roofing E-2 with Felt Composed of 20% Rags, 30% Paper and 50% Heat Treated Oak Fibers. Rated 1.4 out of 3.0 after 23 Years of Exposure.

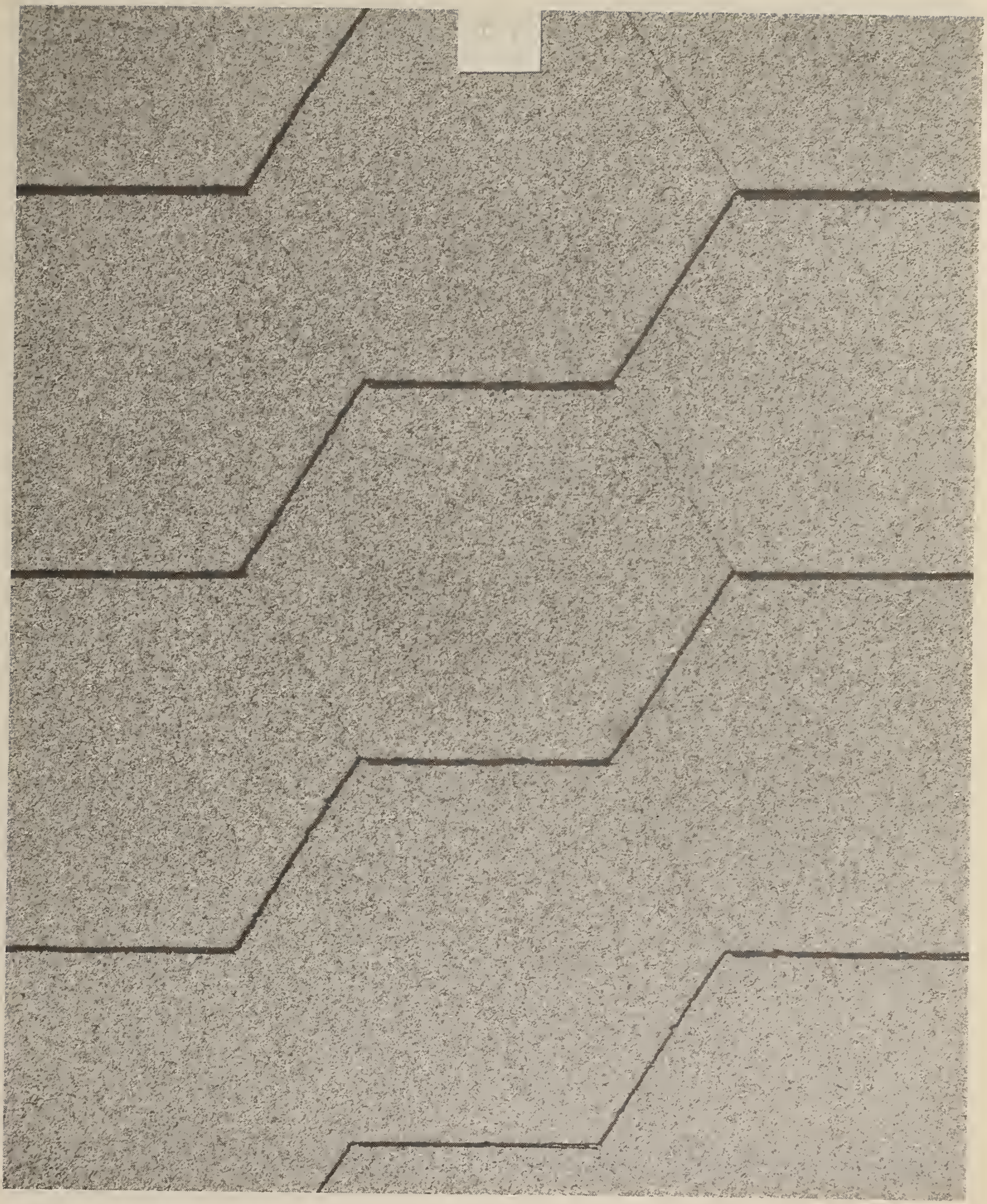

FIGURE 4 - Shingles C-2 with Felt Composed of 37% Rags, 33% Paper and 30% Oak Fibers. Rated 2.1 out of 3.0 after 23 Years of Exposure.

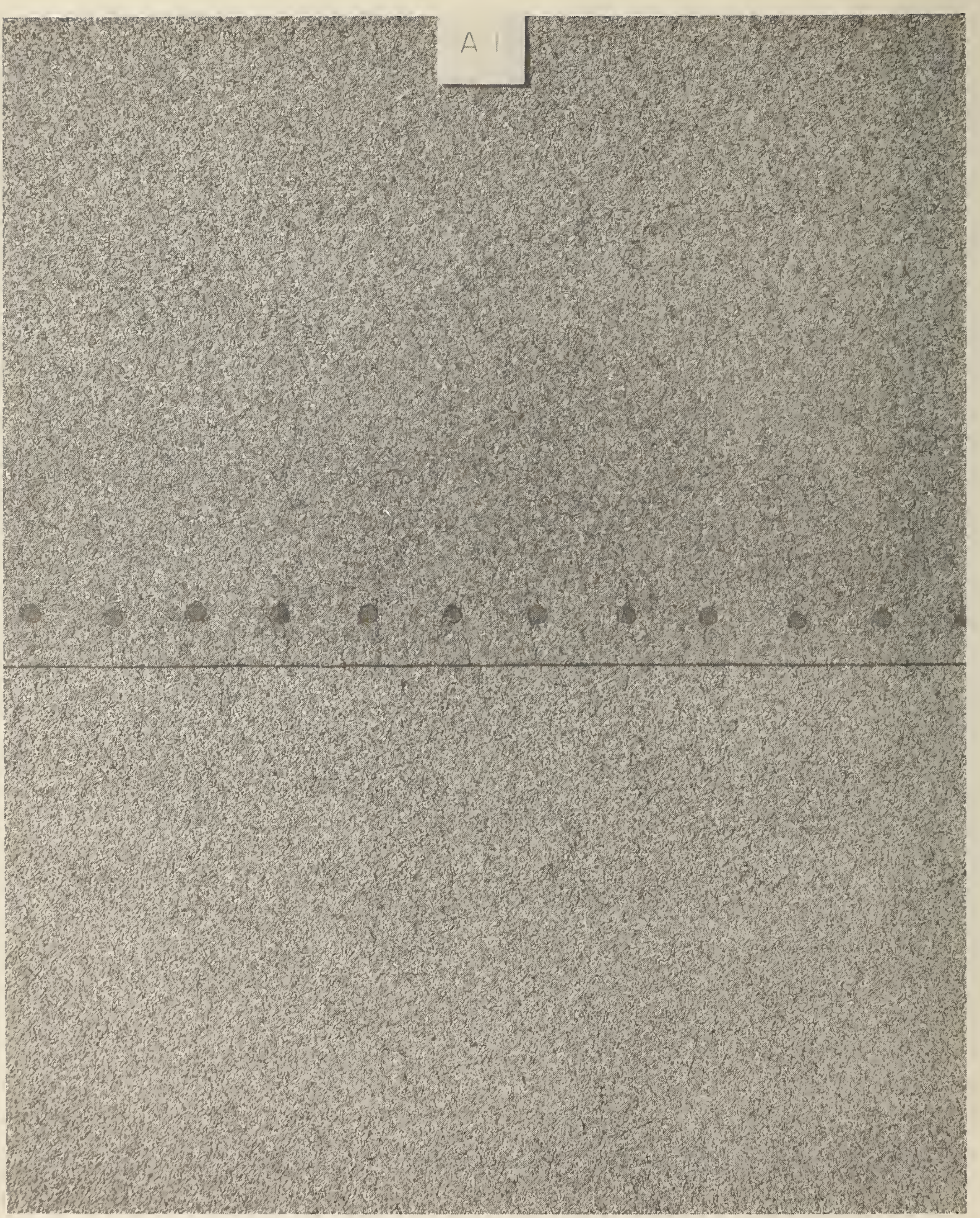

FIGURE 5 - Mineral-Surfaced Roll Roofing A-1 Used as Control, with Felt Composed of 73% Rags and 27% Paper. Rated 1.9 out of 3.0 after 23 Years of Exposure.

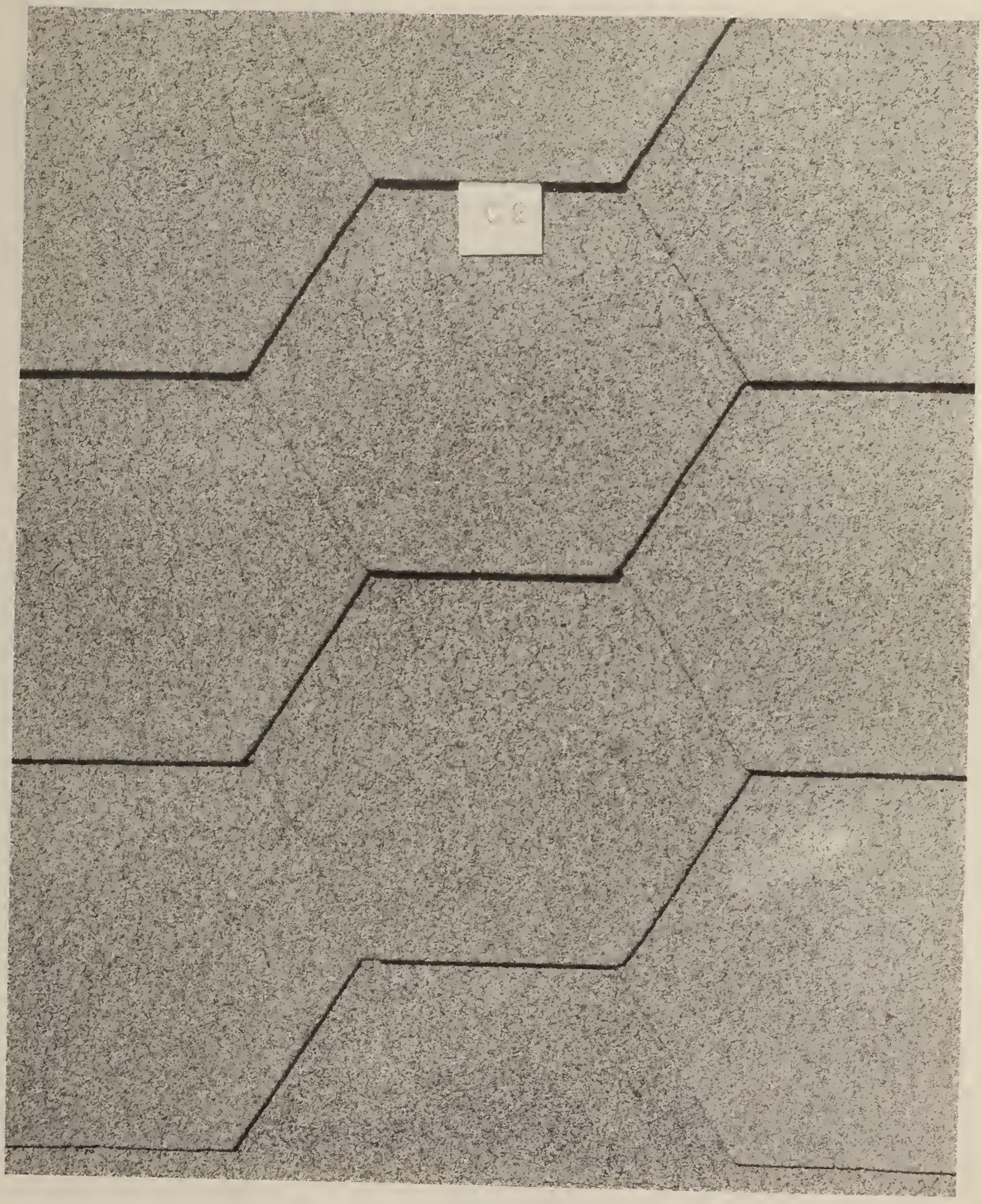

FIGURE 5 - (Continued) Mineral-Surfaced Shingles A-1 Used as Control with Felt Composed of 73% Rags and 27% Paper. Rated 2.7 out of 3.0 after 23 Years of Exposure.

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